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13. ABSTRACT (Maximum 200 words) Studies of multiphoton optical pumping in semiconductors are continuing in narrow gap semiconductors and in GaAs. Our attempts are focused on observing a number of new optical effects including nonlinear absorption and transmission phenomena, enhanced spontaneous and stimulated light scattering processes, etc. The construction of external ring cavity is currently near completion. This will allow us to undertake careful study of multiphoton optical pumping in semiconductors to generate IR radiation and a variety of studies involving narrow gap semiconducting compounds outlined in our proposal. We have studied the feasibility of room temperature operation of a tunable coherent source involving multiple quantum well material. An invention disclosure has been filed with the U.S. Air Force Patent Office for work performed on Multiple quantum well material under this contract. We have also studied the absorption properties of a semiconductor under optical pumping with a white light source. This work has led to the measurement of the temperature by coupling the semiconductor to an optical fiber. We have made			
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Two large laser systems are on order. TACAN Corporation has purchased these lasers along with a variety of test and measurement equipment to enhance the current research under this contract. When they are installed, we plan to explore elementary excitation in optical thin film layers of  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ .



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Nonlinear Optical Interactions in Semiconductors

Semi-Annual Progress Report

August 10, 1983 - February 10, 1984

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Abstract

Studies of multiphoton optical pumping in semiconductors are continuing in narrow gap semiconductors and in GaAs. Our attempts are focused on observing a number of new optical effects including non-linear absorption and transmission phenomena, enhanced spontaneous and stimulated light scattering processes, etc. The construction of an external ring cavity is currently near completion. This will allow us to undertake a careful study of multiphoton optical pumping in semiconductors to generate IR radiation and a variety of studies involving narrow gap semiconducting compounds outlined in our proposal.

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We have also studied the absorption properties of a semiconductor under optical pumping with a white light source. This work has led to the measurement of the temperature by coupling the semiconductor to an optical fiber. We have made another invention disclosure for a fiber optic temperature sensor which will be utilized to measure heat buildup in semiconductor materials as proposed in Part F of our research proposal.

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## I. Research Objectives

The aim of this program is to investigate a variety of novel, non-linear optical processes in semiconductors. These ideas will combine ultrafast spectroscopic techniques to probe the basic physics of the interaction of intense subpicosecond pulses with semiconductor systems. Ultimately, we hope to use these interactions as the basis for ultrafast/cw, tunable infrared sources. Among the processes we are studying, or plan to study, are the following:

A. Multiphoton optical pumping in semiconductors to generate IR radiation, e.g., narrow-gap semiconducting compounds such as  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ .

B. Generation of high-power coherent infrared ( $2\ \mu$  with possible extension to  $100\ \mu$ ) radiation using multiphoton optical pumping in external cavity, with narrow-gap semiconducting compounds.

C. Infrared nonlinear optical processes in a traveling-wave ring cw laser of narrow-gap semiconducting compounds for generation of coherent infrared/submillimeter tunable radiation.

D. Studies with a cw  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  laser in the infrared.

E. Basic dynamics of electron-hole plasma in generating heat in semiconductor materials.

F. Methods of preparing optical thin-film layers by laser techniques to reduce chirp in picosecond pulses from IR semiconductor lasers.

G. Electron-phonon relaxation time and coupling constants in semiconductors.

H. Elementary excitations in polariton (electron-hole-photon)-induced group velocity dispersion in solids.

## II. Accomplishments

Our studies of infrared nonlinear optical processes in a traveling-wave ring cw laser of narrow-gap semiconducting compounds are continuing. During the past six months, we have succeeded in constructing a state-of-the-art ring cavity (part 3 under Statement of Work). The advantage of our new configuration is that it can be operated at room temperature, and with lower optical powers than existing semiconductor lasers. Furthermore, it can provide tunable output. We have recently made an invention disclosure to the U.S. Air Force for this novel system. The gain medium consists of an active media of multiple quantum well (MQW) material composed of approximately 100 Å layers of semiconductor to form many periods of a layered structure. The external cavity operation will allow mode-locked, pulsed or continuous operation and independent control of output power and frequency output.

Our invention provides several novel features: 1) It has a long shelf life and should not undergo thermal or photochemical degradation. 2) It is operable as a laser at room temperature as well as at temperature above or below room temperature. 3) In contrast to dye lasers,

there is no pressure or jet fluctuations. 4) By the use of a variety of semiconductors to form the multiple quantum well, we will not be restricted to those materials that can be formed as p-n junctions. The experimental work is still underway and a few papers providing detailed analysis of the research will be completed during the next few months.

Our studies of basic dynamics of electron-hole plasma in generating heat in semiconductor materials (item 5 under Statement of Work) is continuing. To make a systematic measurement one needs a very sensitive temperature sensor. Recently, we have made an invention disclosure for a fiber optic temperature sensor which utilizes a semiconductor sample as a sensing media. Light is guided in an optical fiber to the semiconductor sample and back to the analyzing electronics. The band gap energy of the semiconductor decreases with increasing temperature. Consequently, the absorption of light in the energy region of the band gap changes with temperature. From the measured light absorption, the temperature of the semiconductor sample can be calculated. The above sensor can operate in an environment of changing high electric or magnetic field without being influenced by those environmental perturbations. Detailed analysis and description of the invention is summarized in the invention disclosure and a paper which will soon be submitted for publication.

### III. Invention Disclosures

1. Semiconductor platelet based, fiber optic temperature sensor.
2. Optically pumped room temperature narrow gap semiconductor laser using superlattice as a gain medium.

### IV. Personnel

- Dr. Michael M. Salour, Principal Investigator
- Dr. James M. Bechtel, Senior Scientist
- Dr. Gerhard Schöner, Postdoctoral Fellow
- Mr. Meinrad Steiner, Design Engineer
- Mrs. Joan I. Tukey, Contract Administrator
- Mrs. Leslie Marshall, Administrative Assistant
- Dr. James H. Bechtel is working very closely with the Principal

Investigator on the performance and implementation of the current AFOSR program. Since joining TACAN Corporation last year, Dr. Bechtel's pioneering contribution has enhanced the productivity of our proposed research.

- Dr. Gerhard Schöner has been with TACAN Corporation since August of 1983. He has been working with the Principal Investigator and has played an important role in the measurement of heat in bulk semiconductor material and the invention of the fiber optic temperature sensor. Dr. Schöner has a Ph.D. in Physics from the University of



Graz in Austria and for the past few years he has been a member of the technical staff at Siemens Research Laboratory of Optics in Munich, W. Germany.

- Mr. Meinrad Steiner joined TACAN Corporation in the Fall of 1983. He is an expert in digital and analog electronics and computer programming. Mr. Steiner holds a Bachelor of Science degree in Electronic Design and his many years of experience has proven to be invaluable for the experimental aspects of our current program.

- Mrs. Joan I. Tukey has been the contract administrator. Mrs. Tukey holds a Bachelor of Science degree from the University of Minnesota and a Master of Science degree in Accounting from Georgetown University. She currently administers government contracts at TACAN Corporation.

- Mrs. Leslie Marshall is an administrative assistant at TACAN Corporation. She holds a Bachelor degree from the California State University, Fullerton.

- Mr. John M. Malloy, who has been working with TACAN as a management consultant in the areas of operations and contract administration, will continue interfacing with TACAN on contract management. He holds an MBA from Harvard Graduate School of Business Administration.

- The accounting firm of Price-Waterhouse performs all internal audits for TACAN Corporation.

## V. Coupling

### A. C.N.R.S., Physique du Solide et Energie Solaire

We have an ongoing interaction with Dr. Christian Verié on the growth of high quality narrow-gap semiconductor crystals of  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ . In the past, Dr. Verié has collaborated with the Principal Investigator on the growth of such crystals and we are currently discussing the possibility of a joint paper.

### B. Dr. D. C. Reynolds, Wright-Patterson AFB, OH

Dr. Donald Reynolds has provided us with a large, excellent quality CdS and GaAs crystal for use in nonlinear optic experiments. The Principal Investigator has visited Dr. Reynold's crystal growing facilities and we expect to increase our interaction in the future.

### C. Professor N. Bloembergen, Harvard University

In the past, we have collaborated with Professor Bloembergen and his research group at Harvard University. Professor Bloembergen has visited our laboratory in La Jolla during the past year and we expect to perform another joint publication in the future.

### D. Professor W. D. Laidig, North Carolina State University

We have an ongoing interaction with Professor Laidig of North Carolina State University. We have visited his crystal growing facilities and the availability of an MBE machine in his laboratory has made

possible a number of joint efforts which is currently underway at TACAN Corporation. We regularly discuss optical pumping and four-wave parametric mixing in multiple quantum well material and plan to publish together.

E. TRW, Hughes Research Laboratory, Hewlett-Packard Research Laboratory

We have occasional contact with a number of scientists at TRW (Los Angeles), Hughes Research Laboratory (Malibu, CA) and Hewlett-Packard Research Laboratory (Palo Alto, CA). We have received a number of enquiries from many other laboratories (both from the government and industry) about the status of our optically pumped semiconductor laser and intracavity nonlinear optical techniques developed under our AFOSR contract. The Principal Investigator has given invited lectures at the above laboratories and a number of colloquium talks at various universities and government laboratories.

VI. Expansion in Facilities and Equipment

On April 1, 1984, TACAN Corporation will relocate its headquarters and laboratories to Carlsbad, California. This facility, located at 2111 Palomar Airport Road in Carlsbad, California, contains much larger laboratories which are specifically designed to accommodate a major expansion in our capital equipment pool. A number of large frame lasers, test measurement equipment, data processing systems,

vibration free optical tables, crystal polishing facilities, fully equipped mechanical and electronic shops, etc. are part of this expansion. We feel this expansion and specialized capital equipment purchased by TACAN Corporation will provide a unique environment and a major enhancement to the productivity of our current research.